SCIENTIFIC AMERICAN

50

TRENDS

- Wireless Power
- Drug Delivery
- Sustainable Fuels
- Toxic Housewares
- Ultrameasurement
- Malaria-Free Mosquitoes
- Bioinspired Materials
- Diagnosing Alzheimer's
- Optical Chips
- Prion Disease Treatments
- Sun Power
- Understanding Stem Cells
- Chip Printers
- Prosthetics
- Intelligent Route Finders

Technological overoptimism lurks as a persistent risk to both professional and amateur watchers of advances, from artificial intelligence to the flying car. But sometimes new technologies actually live up to some of the wildest expectations for them.

This year's SciAm 50 awards are replete with instances of new machines or chemicals that come close to the true meaning of innovation as something entirely new. One winner has created an instrument that measures fluids in zeptoliters, or sextillionths of a liter. (You know, the zeptoliter, the measurement unit that is 1,000th of an attoliter?)

Another innovator has devised a method that could recharge a phone without plugging it in. All you would have to do is sit at the dining room table, phone in pocket, a few feet away from a recharging coil hidden in the ceiling. Still another visionary is paving the way for treating mysterious and deadly prion diseases such as mad cow and kuru.

Award winners highlighted here have the potential to contribute much more to human health, consumer electronics and numerous other fields than if they were simply offering another antidepressant that tweaked serotonin levels or ratcheting up the speed of a microprocessor. What they have done is decidedly new.

—The Editors

SCIAM 50 RESEARCH LEADER OF THE YEAR

The Wellcome Trust Case Control Consortium

U.K.

A massive genetic study turns up the complex roots of major diseases

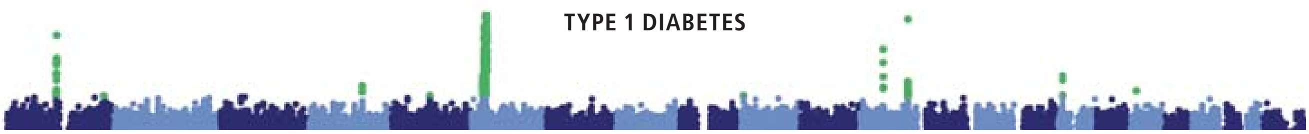
With genetic scientific advances reported almost daily, it sometimes seems as if we are merely waiting for researchers to discover the gene at fault for every human disease. The complex genetic basis of many common diseases, however, complicates prediction, diagnosis and treatment.

The Wellcome Trust Case Control Consortium (WTCCC), a constellation of more than 50 British research groups, took on the mammoth challenge of ferreting out the causes of diseases in which multiple genes are implicated. Last June they reported the findings of a study that scanned for specific gene variations among 17,000 British citizens: 2,000 each from patient groups diagnosed with bipolar disorder, coronary heart disease, Crohn's disease, rheumatoid arthritis, hypertension and diabetes types 1 and 2, as well as 3,000 unafflicted who served as a control group. The large scale of the study was unprecedented and so was the payoff: 24 locations in the genome were found to be associated with six of the seven diseases.

The WTCCC compared the genomes of each affected group with those of the controls and zeroed in on locations where DNA bases differed between the two groups. The size of the study was essential in enabling the researchers to spot rare anomalies. Some of the signals were in coding regions of genes; some were in noncoding regions that might regulate other genes; and some were in "gene deserts"—noncoding regions with no identified function. The variants themselves may not actually be responsible for the diseases. But they serve as signposts for other researchers to investigate DNA at a fine scale.

Every person possesses a certain pattern of "polymorphisms" in the six billion nucleotides of their genomic DNA—three billion for each of the two sets of chromosomes. The statistical pattern of how these variations occur, provided by studies such as the one conducted by the WTCCC, will help physicians calculate the chances that a patient could develop symptoms of a hereditary disorder. The ultimate goal of this research is personalized medicine in which patients submit a blood sample and have their entire set of genes analyzed to determine predisposition to chronic diseases, the best food and exercise regimens to stay healthy, and which drugs and dosages will be most effective when illness does strike. —*Kaspar Mossman*

GENOME-WIDE SCANS turned up gene variants associated with disease, such as those for type 1 diabetes, shown as green highlights on a representation of chromosomes.



SCIAM 50 BUSINESS LEADER OF THE YEAR

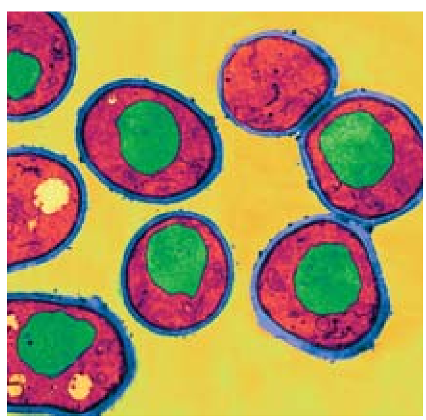
Amyris Biotechnologies

Emeryville, Calif.

The emerging field of synthetic biology provides candidates for a new generation of biofuels

Ethanol is not the most energy-dense of fuels nor the cheapest. Consequently, Amyris Biotechnologies in Emeryville, Calif., has come up with a potentially better solution. It did so by starting with a long roster of organic compounds from which it chose potential replacements for gasoline, diesel and jet fuel that could be burned in modern engines and would be compatible with the existing petroleum infrastructure. Then the company used custom-designed microbes to produce the new fuels by fermentation from a conventional ethanol feedstock.

To create the novel strains was no small genetic feat. The task required sub-



YEAST microbes, once genetically engineered, can boost biofuel yields dramatically.

stantial alterations to the yeast genome. Genes from the original plant source and two other organisms were inserted, and a preexisting biochemical pathway was carefully adjusted. The engineered yeast boasted a millionfold increase in yield.

A leader in the emerging field of synthetic biology, Amyris is well known for developing a strain of yeast for large-scale manufacture of a precursor to the antimalarial drug artemisinin, for which the Asian plant source is in short supply. The company, chosen in 2006 by the World Economic Forum as a Technology Pioneer, is now close to its goal of supplying cheap industrial quantities of artemisinin to developing countries.

Amyris decided that its expertise could prove equally profitable when applied to biofuels. It initiated a search for fuels that could be produced in the lab and that met criteria on energy content, volatility and water solubility.

The difference between engineering microbes to produce drugs versus fuel is that, ounce for ounce, drugs are much more valuable: a fuel end product has to be cheap enough to burn. Amyris will have to optimize each microbial strain so that it cranks out fuel without poisoning itself and produces enough fuel molecules so that it is economically worthwhile to grow. In the history of the large-scale chemical industry, the subtlety of technical expertise involved in this project is without precedent. Yet Amyris, which last June added several oil industry veterans to its management, has shown that it means business. —*Kaspar Mossman*

SciAm 50 POLICY LEADER OF THE YEAR

X Prize Foundation

Santa Monica, Calif.

The lure of multimillion-dollar prizes prompts inventors to pursue breakthroughs in space travel, DNA sequencing, automotive fuel efficiency, and robotics

In 1927 the aviation world marveled at Charles A. Lindbergh's nonstop flight from New York to Paris. Lindbergh was in it for more than thrills: he was after the $25,000 Orteig Prize. In a 21st-century encore, the 12-year-old nonprofit X Prize Foundation conceives and manages competitions for daring innovators.

The foundation's game plan is to define an exciting target that benefits humanity, bait it with a large stack of cash, and draw out the best in design and invention from private, nongovernmental teams. The competitors, the thinking goes, will invest much more in technology chasing the prestige of the prize than the foundation will hand out at the awards ceremony.

Events have borne out this prediction. The foundation set a goal in 1995 "to make space travel safe, affordable and accessible to everyone through the creation of a personal spaceflight industry." In 2004 Mojave Aerospace Ventures won the Ansari X Prize as the first team to build a space plane that could reach low-Earth orbit, return to Earth and repeat the flight within two weeks. Twenty-six teams entered the contest and collectively spent more than $100 million on research.

The second prize, which the foundation offered in late 2006, is the $10-million Archon X Prize, for the first private team to sequence 100 human genomes in 10 days at a cost of less than $1 million. At least four teams have already signed up for the challenge of inventing an instrument that will correctly sequence 98 percent of each genome with no more than 60,000 errors.

The winning technology would accelerate deployment of new discoveries such as genome-wide association studies, which analyze large patient groups to identify genes responsible for complex hereditary diseases. A prominent supporter of the Archon X Prize is Stephen Hawking, the renowned theoretical physicist who suffers from amyotrophic lateral sclerosis.

Last April the foundation also offered the Automotive X Prize, for the first 100-mile-per-gallon production car. And in September the group announced the $30-million Google Lunar X Prize purse for the first private groups to land spacecraft on the moon. Money may be an object for some, but there is no doubt that the challenges set by the X Prize Foundation light a fire under innovators worldwide. —*Kaspar Mossman*

AMBITIOUS GOALS that benefit humanity, such as a private robotic moon mission, serve as the rationale for the X Prize Foundation.

COURTESY OF X PRIZE FOUNDATION

Connections to an Untethered Future

Delivering electric power through the air cuts the final cord

Although laptops, cell phones and other gadgets give us remarkable mobility, we can roam untethered only for as long as our batteries hold out. Photonics researcher Marin Soljačić of the Massachusetts Institute of Technology wants to eliminate that shackle by delivering wireless electricity, or WiTricity.

Soljačić hung a copper coil 0.6 meter (two feet) in diameter from a ceiling, then hung another coil about 2.1 meters (seven feet) away, with a 60-watt lightbulb dangling from it. When he plugged the first coil into a power source, the lightbulb on the second coil lit up. Electric current in the first coil established a magnetic field that induced current in the second one.

The iPhone's "multi-touch" screen gives the user access to a standard keyboard, streaming video, music and a list of voice mails.

Many motors exploit this effect, but normally induction works only across gaps of a few millimeters, dying off rapidly with greater distance. Soljačić tuned his coils to resonate, allowing efficient energy exchange over a distance. Future implementations of his system might enable laptops and cell phones to recharge when they are in a room equipped with a resonance emitter.

The human impulse to cut the cord runs deep. Apple released the iPhone as an ultimate wireless interface, and people lined up to pay $600 for it. The handheld device combines all the functions of an advanced mobile phone with those of the latest iPod, thereby allowing users to wander freely while making phone calls, accessing the Web, sending text messages and e-mail, taking photographs, listening to music and watching videos. Although some earlier phones had offered many of these functions, the iPhone's full-size "multi-touch" screen gave customers far more flexibility, including use of a standard keyboard for messaging, streaming of YouTube video and a visual list of voice mails—not to mention access to iTunes, by far the dominant online music source.

Wireless sensors also gained flexibility. Reduced to the size of rice grains or dust, they can mount a vigil for chemical and biological weapons or check for moisture content in the soil. Already they are changing how people monitor the world. A major barrier, however, has been how to know if such networks of randomly distributed sensors leave gaps in coverage or if the sensors' ranges overlap, thus wasting the precious bits of power they may carry.

Robert Ghrist, a mathematician at the University of Illinois at Urbana-Champaign, and mathematics professor Vin de Silva of Pomona College harnessed the science of mathematical homology to answer both questions. Homology analyzes the points, lines and geometric arrangements within shapes. By treating sensors as points, pairs of sensors as edges, and collections of edges as shapes, Ghrist and de Silva devised algorithms that can tell whether a sprinkled network of sensors overlap or leave gaps.

The advantage of Ghrist's and de Silva's algorithms is that they only need to know which sensors are within range of one another, not where each sensor actually is; they eliminate the need for expensive global-positioning circuits or the manual mapping of circuits. Knowing the locations of gaps and overlaps, network operators could turn up the power of certain sensors or strategically add new ones to fill in blank spots. *—Mark Fischetti*

Getting from Here to There

A protein borrowed from the rabies virus gets a drug to where it is needed

As hard as it is for scientists to develop new drugs, sometimes just getting the drug to where it needs to act is equally challenging. Nowhere is this more true than in the brain, where blood vessel walls are tightly knit, keeping most large molecules from seeping out of the bloodstream and into brain tissue. This blood-brain barrier is a formidable obstacle to delivering certain types of treatments for neurological diseases, but Manjunath N. Swamy and his team at Harvard Medical School's Immune Disease Institute devised a clever way to sneak a drug through and insert it directly into brain cells.

Some viruses that specialize in infecting the nervous system, such as rabies and herpes, are adept at penetrating the blood-brain barrier. Swamy's group exploited that capability by disguising a drug with a small protein normally found on the surface of the rabies virus. The protein is believed to unlock a passageway through the blood vessel walls, and a drug molecule hitched to the viral protein was able to penetrate the barrier. Once inside the brain, the protein also allowed the drug to enter individual nerve cells, much as a virus would infect them. The therapeutic molecule used in Swamy's experiments was a small nucleic acid chain, known as a short-interfering RNA (siRNA), which can be customized to target specific genes and suppress their effects, making siRNA delivered straight to the brain a versatile tool for a wide range of uses.

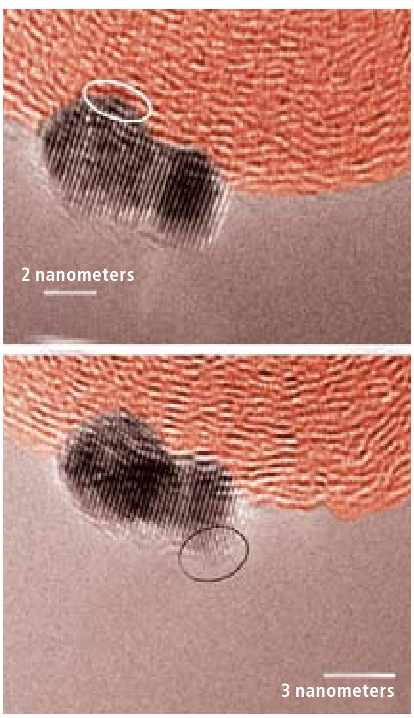
The same can be said of another tiny Trojan horse built by Hans Boumans and his colleagues at the Netherlands Organization for Applied Research. The team's "BioSwitch" consists of a biopolymer cage that can protect or conceal a variety of substances until their release is desirable. Both the cage material and the trigger to discharge its contents can be tailored to specific situations.

For instance, Boumans's group created a germ-killing plastic wrap for meat by encapsulating a bactericidal enzyme inside woven cages of cross-linked starch molecules, then coating the plastic with them. The starch cages remain inert unless bacteria are present and start eating the starch, thus degrading the cage until—surprise—the killer enzyme is released. A similar system could allow unstable food-flavoring molecules to remain encased until they contact enzymes on the tongue or foul-tasting nutrients to stay sealed in their cages until they reach digestive enzymes in the gut. *—Christine Soares*

Fueling Alternatives

Engineers make progress toward new green fuels and energy storage devices

Despite efforts to brew ethanol as a sustainable automotive fuel substitute for gasoline, the plant-derived alcohol has its drawbacks. A gallon (3.8 liters) of ethanol, for one, contains almost a third less energy than the same volume of gasoline.



Gold clusters (*circles*) retard the oxidation of a platinum catalyst in a fuel cell.

FROM "STABILIZATION OF PLATINUM OXYGEN REDUCTION ELECTROCATALYSTS USING GOLD CLUSTERS," BY J. ZHANG, K. SASAKI, E. SUTTER AND R. R. ADZIC, IN *SCIENCE*, VOL. 315; 2007. REPRINTED WITH PERMISSION OF AAAS

So when James A. Dumesic and his fellow chemical engineers at the University of Wisconsin–Madison developed a straightforward way to extract a synthetic fuel from sugar that in many ways surpasses ethanol, the scientific community took notice. Called 2,5-dimethylfuran, or simply DMF, the fuel possesses an energy density equivalent to that of gasoline. It is also insoluble in water and stable in storage. Although chemists have long known about the compound, volume production has been tricky. The new two-step process makes improvements in an intermediate manufacturing step that was a barrier to mass production of DMF.

Beyond finding new alternative fuels for internal-combustion engines, researchers are working on fuel cells that offer another path toward environmentally acceptable power. The key to an effective hydrogen, or proton-exchange membrane (PEM), fuel cell is the microthin coating of platinum particles on the positively charged electrode, where oxygen molecules split into individual charged atoms.

Chemist Radoslav R. Adzic and his team at Brookhaven National Laboratory have found a way to stop the platinum on the electrode's surface from oxidizing, which slows down power-generating chemical reactions and also often causes its membrane to degrade, rendering the cell useless. By spraying the electrode with nanoparticles of gold, Adzic's team made the platinum layer resistant to dissolving and helped it retain most of its original catalytic efficacy.

To produce electricity, most PEM fuel cells must be supplied either with hydrogen or with hydrocarbon compounds that can be catalytically decomposed into hydrogen. Some prototype fuel cells, however, resemble biological cells in that they use chemical enzymes to break down sugars—a special class of hydrocarbon molecules—to generate electrons. Unlike living cells, they typically soon run out of the enzymes necessary to sustain the reaction.

Electrochemist Shelley D. Minteer and her colleague Tamara Klotzbach, both at Saint Louis University, have developed a method to replenish the enzymes in a sugar-powered fuel cell as they degrade with use. The researchers have come up with a polymer wrapping for an enzyme, which keeps the catalytic molecule active for months instead of days. *—Steven Ashley*

Fighting Toxins in the Home

Everyday materials may pose health and environmental threats

Ordinary plastic items may cause sickness.

Researchers are continually finding new evidence that common items in our kitchens, bathrooms and toy chests can make us sick. One of the most insidious substances is bisphenol A, a component of the light plastics used in baby bottles and many other consumer products. Over the past several years, scientists have reported that low levels of bisphenol A can disrupt cell division, leading to spontaneous miscarriages and birth defects such as Down syndrome.

In early 2007 a team led by Patricia A. Hunt of Washington State University found that small amounts of bisphenol A interfered with the growth of egg cells in developing female mouse embryos. As many as 40 percent of the eggs from fetuses exposed to bisphenol A had an abnormal number of chromosomes. This stunning finding showed that the chemical's effects can run through three generations: the pregnant mother's exposure damages the daughter's reproductive cells, which in turn disrupts the development of the daughter's own children.

The National Toxicology Program, which is part of the National Institutes of Health, is currently reviewing the safety of bisphenol A. In the meantime, some physicians advise pregnant women to avoid drinking water from plastic bottles, especially once the containers become visibly scratched or scuffed, which may indicate that they are leaching the hazardous chemical.

Toxic household items also pose a danger to the environment. Unused pharmaceuticals are a particularly serious threat because consumers often flush them down the toilet, sending the potent molecules into rivers and lakes. Discarded birth-control pills can trigger reproductive problems in fish, and surplus antibiotics can enhance the spread of bacteria that are resistant to the drugs. In an attempt to tackle this problem, the American Pharmacists Association and the U.S. Fish and Wildlife Service signed an agreement last year to launch a public-awareness campaign to change consumer habits. When people pick up their prescriptions, they will be advised to dispose of their unused pharmaceuticals through hazardous-waste collection programs. If such programs are not locally available, the next best option is crushing and diluting the medicines, then sealing them in plastic bags and dumping them in the trash. (Some narcotic drugs will be exempt from the recommendations because of the risk that addicts will retrieve the pills from garbage cans.)

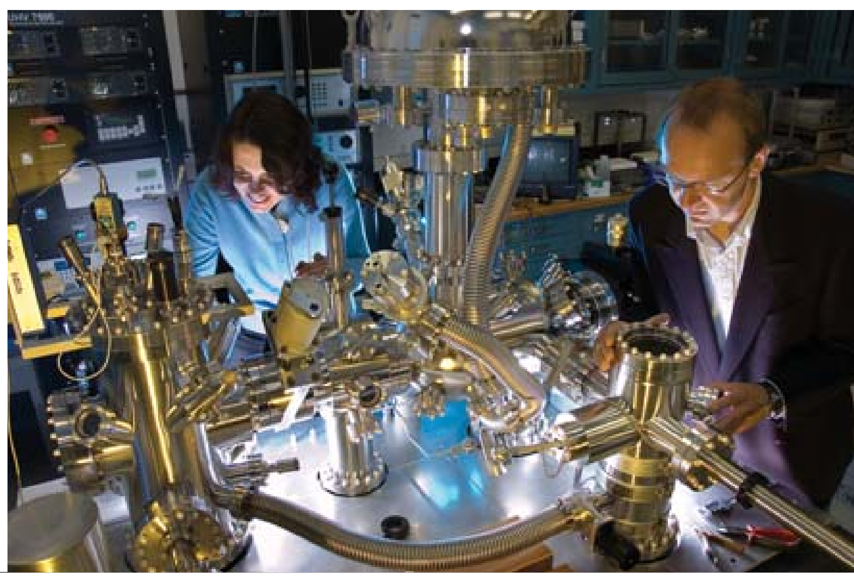
An even better solution would be the establishment of incentives to encourage consumers to return their unused drugs to pharmacies. Pilot programs of this type are now operating in California, Washington State and Maine. —*Mark Alpert*

Advances in Ultrameasurement

Zeptoliter pipettes and quantum rulers give new meaning to the word "small"

Scientists use pipettes when they need to dispense well-defined volumes of liquid. Existing pipettes can deliver fluid volumes as small as an attoliter—a quintillionth, or a billionth of a billionth, of a liter.

Physicists Peter W. Sutter and Eli A. Sutter of Brookhaven National Laboratory have broken that lower limit by constructing a pipette that metes out a droplet measured in a unit that is a thousandth as small—a zeptoliter (a sextillionth of a liter). Such a minute volume



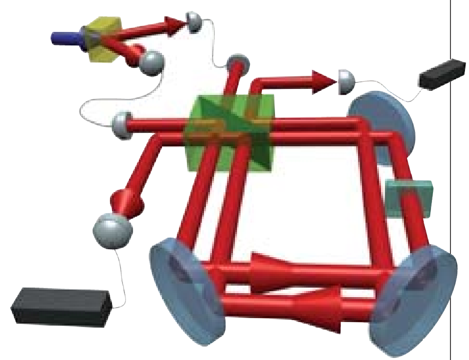
Eli A. Sutter and Peter W. Sutter built the world's smallest pipette, which helped to show that droplets of liquid metal freeze differently than scientists expected.

KRISTY-ANNE GLUBISH *Design Pics/Corbis (top)*; COURTESY OF BROOKHAVEN NATIONAL LABORATORY *(bottom)* can contain as little as 10,000 to as much as a million atoms of metal.

The researchers used a germanium nanowire with a solid reservoir of gold-germanium alloy at one end. They encapsulated the two-micron-long assembly in a carbon shell, which constituted the pipette. Inside a vacuum chamber, they heated and melted the alloy and then aimed an electron beam at the shell's tip. The beam bored an escape hole for the molten metal, which formed a minuscule droplet up to 40 nanometers in diameter and 35 zeptoliters in volume.

If measuring things in zeptoliters is difficult, consider doing so at a scale where the rules of classical physics cease to prevail. Quantum metrology—the field in which quantum mechanics is used to obtain highly precise measurements—has allowed physicists at Hokkaido University in Japan and the University of Bristol in England to almost double the precision of measurement when using photons to gauge distances.

The scientists have built on previous work that uses photons "entangled" in the same quantum superposition of states. The team directed two photonic pairs into an interferometer—an instrument that creates a circular beam path with mirrors in which light waves interfere with one another. Each photon splits, taking separate paths simultaneously. Four photons in an entangled state circulate around the interferometer in one direction, and another quadruplet traverses the loop in the other. The interference produced by the countercirculating photons reveals tiny differences in how far each quadruplet has traveled.



Entangled photons in an interferometer make ultraprecise measurements.

The precision measurements could, for example, be useful when using lasers to etch ultrathin circuits on computer chips. —*Steven Ashley*

Mosquitoes Enlisted to Beat Malaria

Bugs engineered to avoid transmitting the disease could outcompete bugs that do transmit it

Malaria still kills more than a million people a year. Even though low-tech measures such as spraying insecticides and distributing treated bed netting to residents can reduce infection rates, poor countries, where most victims live, cannot afford them.

As an alternative strategy, researchers have tried for years to genetically engineer mosquitoes so they will not transmit the disease. Malaria is caused by protozoan parasites that reproduce inside human liver and red blood cells and are passed from person to person by female *Anopheles* mosquitoes. Although several research teams managed to insert genes into lab-bred mosquitoes that made the bugs less hospitable to the parasites, the altered strains did not reproduce or survive as well as wild strains did.

But last March microbiologist Marcelo Jacobs-Lorena of Johns Hopkins University announced results indicating that engineered insects could outsurvive wild ones. Jacobs-Lorena inserted a gene into *Anopheles* that directs production of a peptide called SM1, which manifests in the mosquito's gut and prevents malaria parasites in rodents from reproducing. The Johns Hopkins team put the transgenic and natural mosquitoes in cages with malaria-infected mice, on which the mosquitoes fed. Over time the mosquitoes reproduced. After nine generations, transgenic bugs made up 70 percent of the overall population. The disease-resistant strains not only competed with the wild ones but survived better.

Mosquitoes can be genetically engineered to avoid passing malaria to humans.

The test did not prove that infection-resistance genes would spread in the wild, but it raised hope that mosquitoes doped with those genes would survive. Hardly a month later, however, biologist Bruce A. Hay of the California Institute of Technology presented evidence that engineered genes can indeed spread throughout a bug population. Working with fruit flies, Hay's team combined a segment of noncoding RNA, known as a microRNA, with a gene that was critical to the development of fruit fly embryos; the researchers then altered that gene so that it was unaffected by the RNA. Next they released the fruit flies into cages with three times as many normal flies. As generations mixed, wild flies that incorporated the microRNA died because it destroyed their unprotected version of the critical developmental gene, whereas flies that bore the altered version of that gene were able to survive. After nine to 11 generations, all the offspring in the cage carried the human-made gene combination. —*Mark Fischetti*

FROM "BEATING THE STANDARD QUANTUM LIMIT WITH FOUR-ENTANGLED PHOTONS," BY T. NAGATA ET AL., IN *SCIENCE*, VOL. 316; 2007. REPRINTED WITH PERMISSION OF AAAS (*top*); SINCLAIR STAMMERS *Photo Researchers, Inc.* (*bottom*)

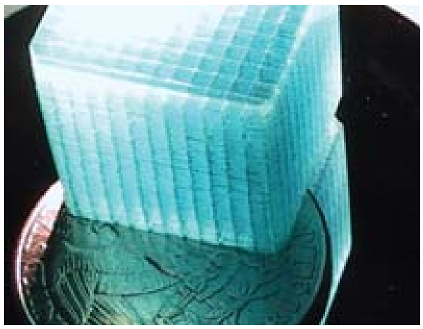
Material World

Scientists take inspiration from nature and instill novel magnetic properties

Cut your finger, and your body starts mending the wound even before you have had time to go and find a Band-Aid. Synthetic materials are not so forgiving, but Nancy R. Sottos, Scott R. White and their colleagues at the University of Illinois at Urbana-Champaign are looking to change all that. They developed a self-healing plastic that contains a three-dimensional network of microscopic capillaries filled with a liquid healing agent. When the material is cracked, the released fluid is hardened by particles of a catalyst that are also sprinkled throughout. The new material can repair minor cracks up to seven times at each location, improving on the group's previous system (in which the fluid was located in individual pockets) that could repair only one injury at each place.

Another feature of natural organisms that scientists have been seeking to emulate is self-assembly. Benoît Roman and José Bico of the City of Paris Industrial Physics and Chemistry Higher Education Institution used the surface tension of evaporating water droplets to fold flea-size origami cubes, pyramids and other structures. Their work used shapes measuring about a millimeter across cut out of a rubbery polymer a mere 40 to 80 microns thick. Thanks to the way that surface tension scales with size, the technique may be effective for self-assembling micron- or nanometer-scale objects made of thinner sheets of polymer.

Electronic components based on plastic or organic materials have become increasingly common in recent years, but the same cannot be said for magnets. Now Robin G. Hicks of the University of Victoria in British Columbia, Rajsapan Jain of the University of Windsor in Ontario and their co-workers have produced a new class of magnets that combine nickel with a variety of organic compounds. The dark, powdery substances remain magnetized up to 200 degrees Celsius. The researchers' ultimate goal is to produce magnetic organic compounds that can be easily molded into thin films or other useful shapes for electronics.



When cracked, the plastic cube releases a self-healing agent from its microvascular network—up to seven times at one location.

It was thought that the only way to see the exotic state of matter known as a Bose-Einstein condensate—in which a collection of particles essentially behaves as one superparticle—involved forbidding, near-absolute-zero cold. Sergej Demokritov of the University of Muenster in Germany and his colleagues were the first to create such condensates at room temperature. Demokritov used small, ephemeral packets of magnetic energy known as magnons, which he generated in yttrium-iron-garnet films by exposing them to microwaves. Magnons are far less massive than atoms and thus can form condensates at much higher temperatures.

—*Graham P. Collins and Charles Q. Choi*

Neurological Insights

Biologists devise a memory on a chip and new ways to tackle Alzheimer's

How does a memory form? To demonstrate how this process occurs at the most basic level, biophysicists at Tel Aviv University replicated that event with neurons attached to a computer chip. Itay Baruchi and Eshel Ben-Jacob placed neurons from rat embryos on a chip surface and connected 64 electrodes to record activity. The researchers witnessed an identical pattern of nerve firings when chemical stimulants were dropped repeatedly at the same location on the chip. After some time, the neurons began to fire in the same way without chemical activation—the point at which they claim a memory becomes imprinted.

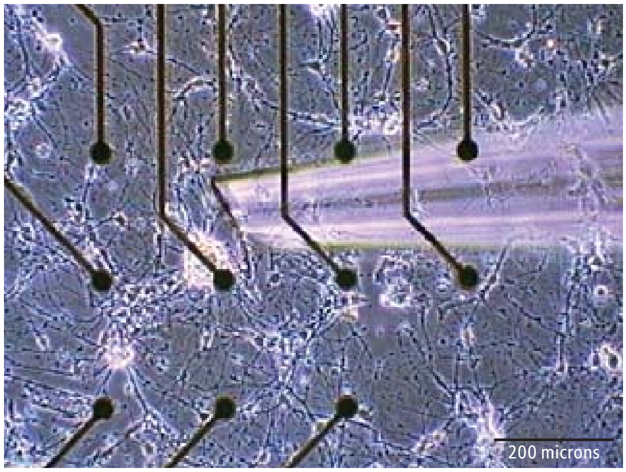
Understanding differences between the proteins made by normal and diseased brain tissues may provide a new approach to diagnostics. Richard D. Smith of the Pacific Northwest National Laboratory and Desmond J. Smith of the University of California, Los Angeles, have created a complex system for analyzing proteins that combines advanced instrumentation with sophisticated image processing to inspect one-millimeter cubes of brain tissue from a pair of normal mice. The investigators determined the abundance of 1,028 proteins in the tissues. Future experiments will use this methodology to compare normal brain tissue with that afflicted by a neurodegenerative disease.

Better diagnostic techniques are needed, in particular, for Alzheimer's disease.

ROB SHEPHERD *University of Illinois at Urbana-Champaign*

Stina M. Tucker, Esther Oh and Juan C. Troncoso of the Johns Hopkins University School of Medicine demonstrated a test using antibodies that bind to the amyloid-beta proteins that form damaging plaques in the brains of Alzheimer's patients. The antibodies adhered to proteins in an early stage of a disease that mimics Alzheimer's in genetically engineered mice. That finding might eventually lead to a test for humans that could be used along with drugs under development to avert the disease through preventive treatment.

Conceivably, that test could be combined with a treatment that uses phages—viruses that infect bacteria—to break up noxious plaque. Beka Solomon of Tel Aviv University showed preliminary proof of this idea by administering phages via a nasal spray to 100 mice genetically engineered to develop Alzheimer's-like plaques. After a year of treatment, the mice had 80 percent fewer plaques than untreated mice. *—Gary Stix*

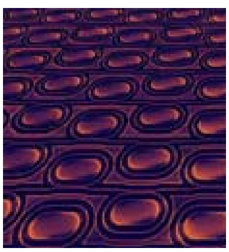


Electrodes record when neurons fire so that a memory forms.

Light Manipulation

New technologies exercise extraordinary control over light

As computer chips become ever more prodigious in their data-processing capacities, the task of shuttling all those gigabits around inside a chip becomes an increasing challenge. Help may be on the way in the form of photonic components, which deal in pulses of light instead of slower packets of electric charge. For several years researchers have been making so-called silicon optical waveguides, in which light speeds along inside the ridge between two channels as if along an optical fiber.


Microscopic loops control light pulses.

But such optical interconnects must deliver their data at precise times, which requires delaying the light pulses by controlled amounts. One method is to send the light pulses into microscopic loops made of waveguides where they circulate dozens of times before continuing on their journey. Yurii A. Vlasov and his coworkers at the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., sent pulses of light through strings of as many as 100 such loops without suffering prohibitive losses of data.

Another way of delaying light in microscopic devices is to use photonic crystal components, which contain carefully designed arrays of holes whose size and spacing exclude light in a certain frequency band (a so-called photonic band gap). A photonic crystal waveguide can consist of a path without holes running through such an array in a thin slab of silicon. The band gap generated by the holes on each side of the path confines the light to travel that route. Takasumi Tanabe and his colleagues at the NTT Basic Research Laboratories in Japan took this scheme several steps forward by temporarily storing photons in a photonic crystal nanocavity—in this case, a small region where the waveguide is slightly wider.

Whereas some researchers want to delay light, others at the Rensselaer Polytechnic Institute led by E. Fred Schubert have created a coating that reflects almost none of it. The coating, about 600 nanometers thick, consisted of five layers of nanorods—titanium dioxide and silica filaments about 25 nanometers in diameter and up to 300 nanometers long—stacked on a transparent semiconductor wafer. Each layer had a lower refractive index than the one below it. The uncoated semiconductor reflected about 12 percent of light incident on it; when coated, it reflected as little as 0.1 percent. The coating could have applications in photonic components, light-emitting diodes and solar cells.

Other investigators are pursuing the far more speculative goal of building quantum computers, which would exploit weird features of quantum mechanics to achieve unprecedented processing capabilities. One approach involves storing quantum data as long-lived states of atoms and transmitting the information with light waves. But combining those two media requires the transfer of delicate quantum states between matter and light. In 2006 a group of researchers led by experimentalist Eugene S. Polzik of the Niels Bohr Institute at the University of Copenhagen and theorist Ignacio Cirac of the Max Planck Institute for Quantum Optics in Garching, Germany, teleported quantum information from a light pulse to a cloud of atoms. *—Graham P. Collins*

ITAY BARUCHI AND ESHEL BEN-JACOB (*top*); IBM (*bottom*)

Progress against Prions

Ideas for treating the human form of mad cow disease begin to emerge

More than 200 cases of variant Creutzfeldt-Jakob disease, the human form of mad cow, have occurred worldwide since the 1990s. No accepted treatment exists for the devastatingly fatal disease or any of the others caused by infection with the malformed, malignant protein particles called prions. Giovanna R. Mallucci and her co-workers at the Institute of Neurology in London have performed an experiment in mice that could lay the groundwork for an eventual cure. Researchers genetically engineered mice to produce the protein PrP for only the first nine weeks after birth. PrP misfolds in the presence of prions, which causes it to produce more prions.

When both the altered mice and a normal group were injected with prions causing the illness called scrapie, both groups experienced a cognitive decline at first. The normal subjects continued to deteriorate. But by 12 weeks, the engineered group, without an ongoing supply of PrP, had recovered memory and normal behavior patterns. The absence of the natural protein did not appear to have an adverse effect on the restored rodents. If this approach proves itself further, it might lead to drugs or gene therapies that diminish PrP.

Blood filters through beads coated with a compound that readily sticks to prions.

Until that happens, the possibility of prions infecting people through the blood supply remains an ever present fear. Robert Rohwer of the Veterans Affairs Medical Center in Baltimore and his colleagues invented a filter that might be able to purge red blood cells of prions. The team members began by searching through a library of millions of chemicals until they discovered a compound, L13, that readily sticks to prions. Scrapie-containing blood filtered through beads coated with L13 and then injected into hamsters did not cause disease in the animals, unlike tainted, unfiltered blood.

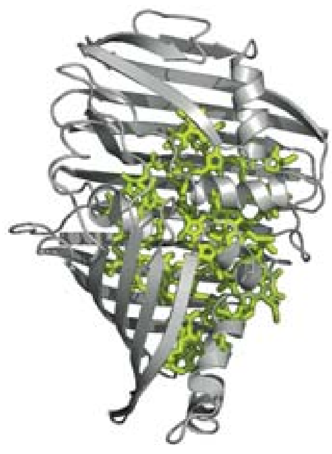
—Gary Stix

Sun Power Gets a Boost

A stolen idea from the plant world could improve prospects for solar power

Photovoltaic cells can generate electricity without adding greenhouse gases to the atmosphere, but solar power is significantly more expensive than the electricity produced by coal- and gas-fired plants. To boost the competitiveness of solar energy, researchers have striven to make solar cells convert sunlight into electricity more efficiently.

Inspiration may come from the most basic scientific research. Investigators are starting to delve into the intricacies of photosynthesis, which converts sunlight into chemical energy with almost 100 percent efficiency. A group led by Gregory S. Engel, formerly at the University of California, Berkeley, and now at the University of Chicago, cooled a green sulfur bacterium to 77 kelvins (–321 degrees Fahrenheit) and then zapped it with ultrashort pulses from a laser, enabling the tracking of the energy flow through the bacterium's photosynthetic apparatus.



Insights into the photosynthesis system for bacteria (*above*) and other organisms may improve solar technology.

The researchers found that by using this spectroscopy technique, they could explain how plants efficiently transfer solar energy to molecular reaction centers for conversion into chemical energy. The previous view of photosynthesis postulated that light-harvesting molecules called chromophores absorbed energy from the sun and then transferred it from one such molecule to another along one of various possible routes until reaching a reaction center.

The study found that in contrast to the prevailing notion, energy moves in a wavelike motion along all the pathways in the system at once, a quantum effect that ensures that the energy takes the most efficient route, arriving at its destination almost instantaneously. Eventually this new understanding may become the basis for an artificial photosynthesis process that can be incor-

MACOPHARMA (*top*); GREG ENGEL (*bottom*) porated into the design of more efficient photovoltaic cells.

Other scientists are devising better ways to use sunlight to heat and cool buildings. Steven Van Dessel of the Rensselaer Polytechnic Institute and his colleagues have developed a prototype system called the Active Building Envelope (ABE), which couples solar panels to thermoelectric heat pumps. Electricity produced by the solar cells goes to the heat pumps, which can either heat or cool the building's interior, depending on the direction of the flow of the current. The research group is now investigating the possibility of creating a transparent ABE system using thin-film photovoltaic cells and thermoelectric materials instead of bulky components. The transparent films could be applied like a glaze to the windows of buildings and to the windshields and sunroofs of cars. —*Mark Alpert*

Stem Cell Control

The essential character of the mother of all cells reveals itself in a set of breakthrough findings

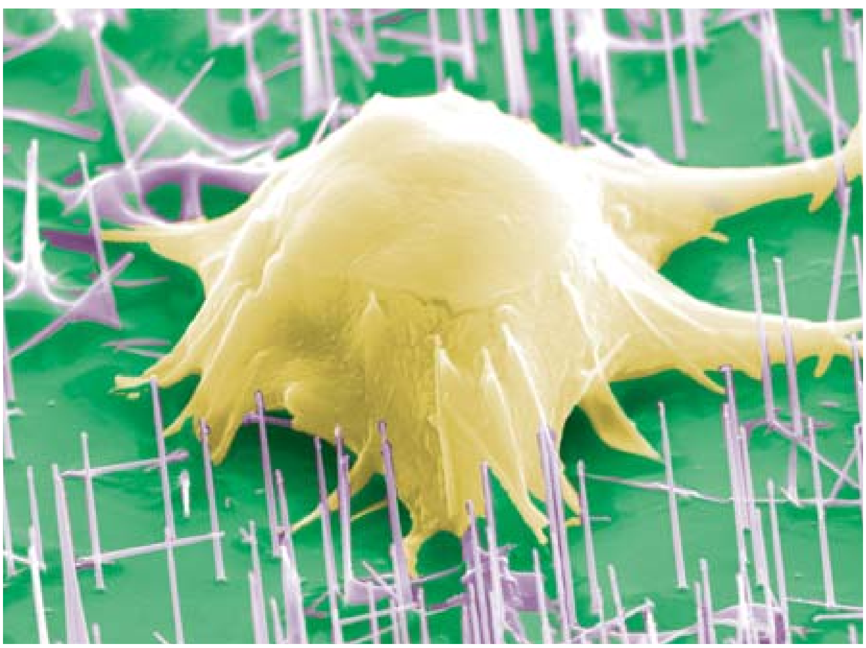
The all-powerful potential of stem cells to become any kind of cell is what makes them so promising for restoring diseased or damaged tissues throughout the body—and also what makes them so difficult for scientists to control. But several breakthroughs represent major strides toward understanding and harnessing the cells' elusive property of inherent "stemness."

Shinya Yamanaka of Kyoto University, who transformed a regular mouse skin cell into a cell with most of the characteristics of embryonic stem cells (ESCs) by turning up the activity of just four genes, demonstrated recently a more precise way of isolating cells "reprogrammed" to an ESC-like state—and several other laboratories have replicated his results.

Coaxing cultured ESCs to go in the opposite direction—to become skin cells or some other type of tissue—is a tricky process involving the cells' own gene activity and signals from their surrounding environment. Peidong Yang of the University of California, Berkeley, and Bruce R. Conklin of the Gladstone Institute of Cardiovascular Disease in San Francisco showed a new way to deliver those external signals by growing ESCs embedded with nanoscale silicon wires. Yang and Conklin envision the technique being used to guide the differentiation of stem cells into specific tissue types through electrical pulses or chemicals transmitted via nanowires.

As some researchers worked on controlling the differentiation of ESCs, others were focused on finding out what keeps adult stem cells in an undifferentiated state. Frank D. McKeon of Harvard Medical School showed last year that the activity of a single gene, known as *p63*, is the key to a cell staying a stem, at least in epithelial cell types, which include a variety of tissues such as skin, prostate, breast and thymus.

There is no shortage of adult stem cells for investigators who want to probe their relation to health and disease, but that is not true for ESC scientists who typically must first create embryos from hard-to-procure eggs. A technique for recycling unhealthy fertilized embryos, which have no other viable use, has promise as a source of ESCs for research. Kevin Eggan of the Harvard Stem Cell Institute and his team used aberrant embryos with extra chromosome sets—which can occur naturally during in vitro embryo creation when two sperm fertilize an egg—as stand-ins for the precious eggs. They found that when the chromosomes were removed and new genetic material introduced, the resulting embryo developed successfully about as often as embryos made from eggs and yielded stem cells that were apparently normal. —*Christine Soares*



Nanowires could deliver signals to prompt a stem cell to differentiate into another cell type.

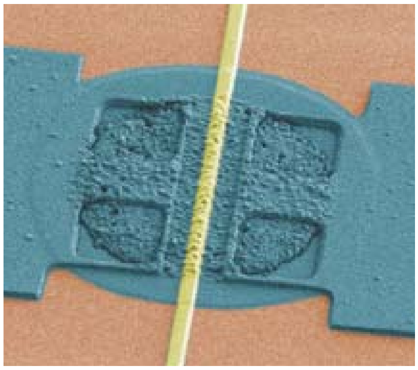
PEIDONG YANG *University of California, Berkeley*

Squirt and Spin

Printers squirt out silicon chips, and the spin of electrons is used in computer logic

We now look back with pity on old computer printers, with their glacial bizz-buzz and annoying perforated-edge paper. A decade from now people will surely look back in pity on the things we call printers today. Three-dimensional printers, capable of producing entire objects, are already coming down in price, and new types of printers can output electronic circuit boards or even entire functional circuits. Now researchers have a printer that outputs silicon chips.

The device, created by materials scientist Masahiro Furusawa of Seiko Epson Corporation in Japan and his colleagues, squirts out polysilane, a polymer of silicon and hydrogen. Once laid down, it can be baked at kitchen-oven-cleaning temperatures to drive out the hydrogen and leave behind crystalline silicon. The technique provides an alternative to the conventional process for producing microchips, which requires refining, stenciling and etching the silicon—a sequence that is both complicated and wasteful: 99 percent of the original silicon is thrown away. The silicon printer is still fussy and does not produce chips with as fine a level of detail. Nevertheless, it might lower the cost of low-resolution silicon devices such as display circuitry and solar cells.



Transistor made from polysilicon was literally printed onto a surface.

Gizmo users of the future will also look back in pity on what flows through those circuits. Right now circuits convey signals by the presence or absence of electrons, ignoring the particles' spin (the quantum analogue of rotation). The emerging technology of spin-based electronics, or "spintronics," seeks to make use of this wasted information. So far its only application has been in hard disks. Researchers have also sought to exploit it in logic gates for computational processing, not least because it takes less energy to flip an electron's spin than to change its direction of motion. The hang-up is that detecting and manipulating spin requires magnets, which are tricky to integrate into silicon circuits.

Physicist Hanan Dery of the University of California, San Diego, and his colleagues have now come up with a workable logic-gate design. A combination of fixed magnets and voltage levels steers electrons based on their spin and the desired gate function. The team outlined a proposal for a spintronics computer based on the gate, but it remains to be seen whether it will work in practice.

—*George Musser*

Making Them Whole

Artificial limbs and a prosthetic arm create a path to better bionics

Research on prosthetics takes its greatest strides during or just after wartime, and the past several years have sadly been no exception. Todd A. Kuiken of the Rehabilitation Institute of Chicago and his team have pioneered "targeted reinnervation," which jacks an artificial arm into the nervous system. They transplant nerves from the shoulder of a lost arm to a patch on the chest. In trying to move the arm, the person causes chest muscles to flex, which electrodes pick up and transmit to the prosthesis. The researchers have begun to experiment with two-way connections, relaying signals from sensors on the arm to sensory nerves.

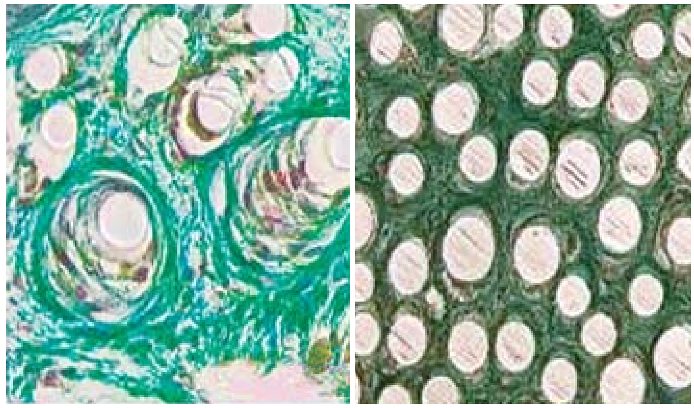
Details about the prosthetic arm by Segway inventor Dean Kamen of DEKA Research & Development Corporation are limited to a YouTube video (www.youtube.com/watch?v=1hzRja9eunY), but it is jaw-dropping. In a demonstration that looks like a scene from *Bionic Woman,* an engineer wearing

Patient at the Rehabilitation Institute of Chicago demonstrates the manual control that can be achieved with one of his protheses.

a prototype arm grasps a water bottle, picks up a pen and scratches his nose. One can only hope that, unlike the Segway, it will be priced at a level affordable to all.

Every year more than 200,000 Americans tear their knee ligaments, which, as the Mafia knows, is a painful and hard-to-treat injury. Cato T. Laurencin of the University of Virginia and his team have developed polymers that serve as tissue scaffolding, promoting the growth of brand-new ligaments. In tests on rabbits' knees, the regenerated ligament supported a third as much tension as a fresh one. To be sure, half the bunnies suffered new ruptures, but Laurencin attributed this to the difficulty of convincing them to go through physical therapy.

—*George Musser*



Polymer fibers (*shown in cross section*) encourage growth of new ligaments.

The Fastest Way to Get There

Novel ways of calculating routes and predicting traffic jams promise less time in the car

Providing directions instantly online has until recently meant that navigational mapping programs, such as MapQuest and Google Maps, often simplify the problem by not considering every possible route to a destination. Scientists at the University of Karlsruhe in Germany have designed a computer application that can quickly calculate the most expedient of all possible driving routes without the need for excessive computation.

Dominik Schultes, one of the project's scientists, designed the program around a simple premise: driving somewhere usually requires crossing major intersections that are sparsely interconnected. Figuring the best route occurs by precomputing the connections between a starting point (or destination) and its nearest major intersections and between all locations where major routes cross each other's paths—so-called transit nodes. When this parsimonious algorithm was tested on densely routed maps of western Europe and the U.S., the route calculations improved by a factor of 100.

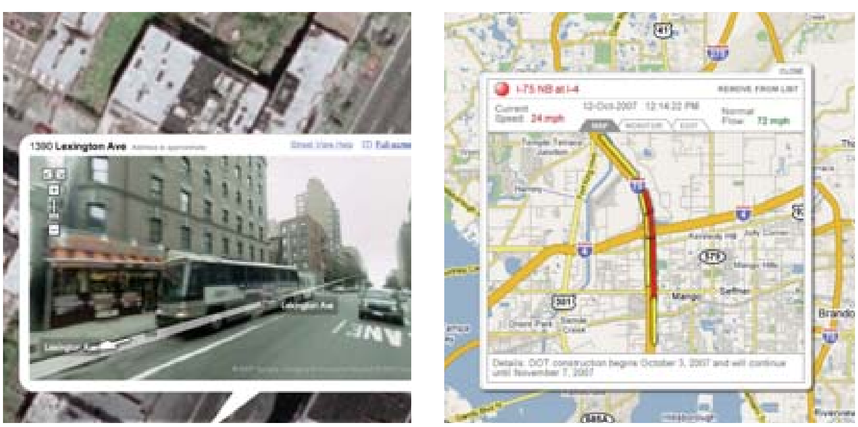
To actually ensure that drivers do not go astray on their road excursion, Google has begun installing an option to its mapping program that provides a street-level navigational view. With a system of successive panoramic snapshots of the suggested route, Google Street View allows travelers to verify the landmarks they will encounter from the driver's seat.

Even with the best directions in hand, unforeseeable traffic can ruin a trip. IntelliOne, a company that explores ways to combine transportation and communications networks, has recently unveiled the TrafficAid, which translates anonymous cell phone signals into an accurate, real-time traffic map.

By harnessing ubiquitous cellular networks, the system avoids having to install separate sensors along traffic routes. Specific servers, instead, can detect a phone's specific location and speed. IntelliOne transfers these signaling data to its database, where detected phones are associated with a certain road, thereby producing accurate and timely information about traffic conditions.

Freed of dependence on traffic information from video cameras, roadside radars and in-pavement monitors, the TrafficAid updates its map of bunched signals more quickly and makes a calculation to within five to eight kilometers (three to five miles) per hour of actual speed.

—*Peter Sergo*



Street View (*left*) adds imagery of U.S. cities to Google's mapping program, whereas TrafficAid (*right*) transforms signals received from cell phones into a real-time traffic map.

FROM "BIOMIMETIC TISSUE-ENGINEERED ANTERIOR CRUCIATE LIGAMENT REPLACEMENT," BY A. COOPER ET AL., PUBLISHED ONLINE FEBRUARY 20, 2007. © 2007 NATIONAL ACADEMY OF SCIENCES USA (*top*); © 2007 GOOGLE IMAGERY/BLUESKY/IMMERSIVE MEDIA2 (*bottom left*); INTELLIONE TECHNOLOGIES (*bottom right*)

See-Through Technology and Better Sleep

A mix of technology accompanies the doings of a maverick researcher

T-ray Vision

In principle, terahertz radiation—which lies between the microwave and infrared segments of the electromagnetic spectrum—could help people safely peer through flesh, plastic, fabrics and ceramics to detect anomalies, from tumors to bombs, for medical or security applications. But for decades, so-called t-ray devices were impractical outside the lab because they were fragile and because they weighed 45 kilograms (100 pounds) or more. Yet after just a few months of work, Brian Schulkin of the Rensselaer Polytechnic Institute created a rugged t-ray imager dubbed the "Mini-Z" that is less than 2.3 kilograms (five pounds) in weight and can fit in a briefcase. A prototype detected flaws purposely embedded in samples of foam used to insulate the space shuttle. Schulkin next plans to develop a handheld t-ray device. —*Charles Q. Choi*

Load-Lightening Backpack

A few hardcover textbooks in a school backpack are enough to cause muscle strain. Lawrence C. Rome of the University of Pennsylvania and of the Marine Biological Laboratory in Woods Hole, Mass., and his colleagues have developed a backpack suspension system that minimizes stress on its wearer. As people walk, they typically bob up and down by several centimeters, which causes a pack to swing up and down. A 2.3-kilogram (five-pound) laptop slams down with 3.7 kilograms (eight pounds) of force when walking and as much as 6.9 kilograms (15 pounds) when running. Using pulleys and bungee cords, the new backpack damps this motion by half or more. In effect, the pack feels about a fifth lighter.

One version even generates electricity—more than seven watts, enough to recharge phones. Rome has set up a company, Lightning Packs, to develop the idea. —*George Musser*

Peer-through technology has gone mobile.

Better Sleep Aid

About nine years ago researchers discovered that the sudden spells of sleepiness called narcolepsy were caused by a deficit of a brain peptide called orexin. Actelion Pharmaceuticals in Allschwil, Switzerland, used this knowledge to create a type of sleeping pill that works by blocking two orexin receptors. Drug tests have shown that the compound known as ACT-078573 induces sleep in both animals and humans. —*Gary Stix*

Antiparasite Weapon

The debilitating parasitic illness known as schistosomiasis infects roughly 200 million people worldwide, making it second only to malaria in importance for public health. Currently just one drug, praziquantel, commonly treats the chronic disease, raising fears that the parasite could evolve resistance against it. Now Conor R. Caffrey of the University of California, San Francisco, and his colleagues have found a new drug that can kill the blood flukes that cause the ailment. They investigated the drug K11777, which interferes with the flukes' digestive enzymes, and discovered that it could eliminate the parasites in lab mice.

If effective in humans, K11777 could work in tandem with praziquantel, with the former taking care of early-stage illnesses and the latter killing later-stage infections. —*Charles Q. Choi*

A new drug may fight the parasites that cause schistosomiasis.

Bird Flu Research for All

Until recently, laboratories doing bird flu research often kept their findings private, with access to many avian influenza gene sequences confined to just 15 facilities globally, potentially hindering them from doing research that could provide new insight into the virus. Instead of entering her avian influenza findings into this database, Ilaria Capua of Vialle University in Padua, Italy, disclosed the results of her studies in the publicly accessible GenBank and boldly rallied her colleagues to follow.

Her efforts helped to pave the way for the Global Initiative on Sharing Avian Influenza Data, a consortium through which findings can be freely shared while giving credit to researchers involved. —*Charles Q. Choi*

BRIAN SCHULKIN (*left*); NATIONAL CANCER INSTITUTE/PHOTO RESEARCHERS, INC. (*right*)

Research Leader of the Year

1. The Wellcome Trust Case Control Consortium

Business Leader of the Year

2. Amyris Biotechnologies

Policy Leader of the Year

3. X Prize Foundation

Other Research, Business and Policy Leaders

Connections to an Untethered Future

4. Marin Soljačić, Massachusetts Institute of Technology (research)
5. Apple (business)
6. Robert Ghrist, University of Illinois at Urbana-Champaign, and Vin de Silva, Pomona College (research)

Getting from Here to There

7. Manjunath N. Swamy, Immune Disease Institute, Harvard Medical School (research)
8. Hans Boumans, Netherlands Organization for Applied Research (research)

Fueling Alternatives

9. James A. Dumesic, University of Wisconsin–Madison (research)
10. Radoslav R. Adzic, Brookhaven National Laboratory (research)
11. Shelley D. Minteer and Tamara Klotzbach, Saint Louis University (research)

Fighting Toxins in the Home

12. Patricia A. Hunt, Washington State University (research)
13. American Pharmacists Association and the U.S. Fish and Wildlife Service (policy)

Advances in Ultrameasurement

14. Peter W. Sutter and Eli A. Sutter, Brookhaven National Laboratory (research)
15. Groups of physicists at Hokkaido University, Japan, and the University of Bristol, England (research)

Mosquitoes Enlisted to Beat Malaria

16. Marcelo Jacobs-Lorena, Johns Hopkins University (research)
17. Bruce A. Hay, California Institute of Technology (research)

Material World

18. Nancy R. Sottos and Scott R. White, University of Illinois at Urbana-Champaign (research)
19. Benoît Roman and José Bico, City of Paris Industrial Physics and Chemistry Higher Education Institution (research)
20. Robin G. Hicks, University of Victoria, British Columbia, and Rajsapan Jain, University of Windsor, Ontario (research)
21. Sergej Demokritov, University of Muenster, Germany (research)

Neurological Insights

22. Itay Baruchi and Eshel Ben-Jacob, Tel Aviv University (research)
23. Richard D. Smith, Pacific Northwest National Laboratory, and Desmond J. Smith, University of California, Los Angeles (research)
24. Stina M. Tucker, Esther Oh and Juan C. Troncoso, Johns Hopkins University School of Medicine (research)
25. Beka Solomon, Tel Aviv University (research)

Light Manipulation

26. Yurii A. Vlasov, IBM Thomas J. Watson Research Center (research)
27. Takasumi Tanabe, NTT Basic Research Laboratories, Japan (research)
28. E. Fred Schubert, Rensselaer Polytechnic Institute (research)
29. Eugene S. Polzik, Niels Bohr Institute, University of Copenhagen, and Ignacio Cirac, Max Planck Institute for Quantum Optics, Germany (research)

Progress against Prions

30. Giovanna R. Mallucci, Institute of Neurology, London (research)
31. Robert Rohwer, Veterans Affairs Medical Center, Baltimore (research)

Sun Power Gets a Boost

32. Gregory S. Engel, University of Chicago (research)
33. Steven Van Dessel, Rensselaer Polytechnic Institute (research)

Stem Cell Control

34. Shinya Yamanaka, Kyoto University (research)
35. Peidong Yang, University of California, Berkeley, and Bruce R. Conklin, Gladstone Institute of Cardiovascular Disease, San Francisco (research)
36. Frank D. McKeon, Harvard Medical School (research)
37. Kevin Eggan, Harvard Stem Cell Institute (research)

Squirt and Spin

38. Masahiro Furusawa, Seiko Epson Corporation, Japan (business)
39. Hanan Dery, University of California, San Diego (research)

Making Them Whole

40. Todd A. Kuiken, Rehabilitation Institute of Chicago (research)
41. Dean Kamen, DEKA Research & Development Corporation (research)
42. Cato T. Laurencin, University of Virginia (research)

The Fastest Way to Get There

43. Dominik Schultes, University of Karlsruhe, Germany (research)
44. Google (business)
45. IntelliOne (business)

See-Through Technology and Better Sleep

46. Brian Schulkin, Rensselaer Polytechnic Institute (research)
47. Lawrence C. Rome, University of Pennsylvania and Marine Biological Laboratory, Woods Hole, Mass. (research)
48. Actelion Pharmaceuticals, Switzerland (business)
49. Conor R. Caffrey, University of California, San Francisco (research)
50. Ilaria Capua, Vialle University, Italy (policy)

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